SOYBEAN OIL

Composition and Physical Properties

Crude soybean oil is ordinarily produced by pressing or solvent-extraction of mature, sound soybeans. Although the method of processing soybeans results in minor variations in the chemical composition of the oil, it is normally found to consist of 95 to 98 percent of the glycerides of saturated and unsaturated fatty acids having, for the most part, a chain length of 18 carbon atoms. Minor components, principally 1.5 to 3 percent of phosphatides and 0.5 to 2 percent of unsaponifiable matter, are present in the crude oil. The fatty acids of the mixed glycerides normally comprise about 12 percent of saturated and 88 percent of unsaturated acids; of the latter oleic acid constitutes 25 to 35 percent, linoleic acid 45 to 55 percent, and linolenic acid 3 to 10 percent of the total acids.

The chemical and physical characteristics of crude soybean oil likewise vary with the method of production, but the following values may be considered as a normal range: Iodine number, 125 to 135; thiocyanogen number, 80 to 85; refractive index, 1.4700 to $1.4740_D^{25°}$; viscosity, 0.50 to 0.65 poises at 25° C.; acid number, 0.5 to 2; flash point, 300° to 320° C.; fire point, 350° to 355° C.; break, 0.1 to 1.00 percent; refining loss, 1.0 to 7.0 percent; Lovibond color, 70Y 12R to 70Y 30R (133 mm. cell).

The chemical composition and properties of soybean oil place it intermediately between the nondrying and the drying classes of oil, and consequently it finds use in both of these channels. At various times in the past 25 years it has been used principally as a drying oil, as a soap oil, and as an edible oil. In recent years the primary outlet for soybean oil has been in the field of edible products, as is evident from the data of the following table.

Factory production and consumption of soybean oil in the United States

Year	Total factory production	Shortening	Oleomargarine	Other edible products	Soap	Drying oil industry	Miscellaneous
	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.	1,000 lb.
1931	---	10,869	623	---	3,816	8,901	2,051
1932	39,445	4,889	3	180	5,571	11,593	1,875
1933	26,533	489	7	460	4,235	14,274	2,626
1934	35,366	2,735	24	509	1,354	13,353	2,109
1935	105,056	52,452	1,740	9,421	2,549	17,871	1,665
1936	225,297	113,897	14,262	21,598	5,023	17,419	3,405
1937	194,411	90,798	31,793	15,530	10,274	17,157	3,038
1938	243,613	143,318	39,885	11,280	10,897	18,847	5,340

For use in the production of soap, in some types of blended paint oils, and in certain miscellaneous products, soybean oil is used with little or no treatment other than settling and filtration. When used in the manufacture of most paints and also in varnishes, enamels, linoleum, oilcloth, printing inks, and similar products of the drying oil industry, it is generally refined, either by one of the so-called mechanical refining processes or by treatment with alkali. For use as a salad or cooking oil, it is alkali-refined, bleached, winterized, and deodorized; and, if the oil is to be used in the production of shortening or oleomargarine, it is subjected to hydrogenation in order to harden it.

Soaps and Detergents

Like most oils and fats, soybean oil may serve as a raw material for the production of soap, although it is not especially well suited for this purpose. In one year during the first World War, when an acute shortage of fats occurred in all countries, the United States consumed 124 million pounds of Manchurian soybean oil in the production of soap; but with the return of normal conditions its use for this purpose decreased quite markedly. At the present time about 10 million pounds of soybean oil are consumed annually in the soap industry, together with considerable quantities of so-called "foots" which are produced during the process of refining the oil. Except when it is blended with other fats, soybean oil, in general, is not adapted to the production of high-grade soaps for toilet purposes and for washing delicate fabrics.

Soybean oil and its derived fatty acids can be converted into sodium and potassium soaps which are semi-solid or liquid products. Soaps of this type are primarily used for washing cars and other metal surfaces and for cleansing marble, tile, and terrazzo floors. Calcium soap derived from soybean oil is used in certain types of lubricating greases. When properly hydrogenated, soybean oil can be substituted for tallow in the production of laundry and certain types of toilet soaps, while the soaps derived from the sulfonated oil are used as wetting and emulsifying agents. In the course of the conversion of soybean oil into soap or fatty acids, there is simultaneously produced approximately 10 percent of glycerine which is recovered and marketed for various purposes.

Paints, Varnishes, and Related Products

The drying or semidrying property of soybean oil results principally from its content of linoleic and linolenic acids which normally comprise 45 to 55 percent and 3 to 10 percent, respectively, of the total acids of the oil. The drying and film-forming properties of the crude oil are inhibited by the presence of phosphatidic and anti-oxygenic materials which tend to retard the uptake of oxygen; and, as a consequence of the presence of about 25 percent of oleic acid, the resulting film is more flexible than that produced by linseed oil under the same conditions. Failure to appreciate the effect of the natural inhibitors which are present in crude soybean oil has been responsible for some of the failure in adapting it to certain uses in the drying oil field.

With increasing knowledge of the best methods of treating soybean oil, it has found wider application in the manufacture of paints, varnishes, enamels, linoleum and allied products, printing inks, synthetic resins, caulking compounds, core oils, and factice. Although detailed estimates are for the most part unavailable, it is known that the soybean oil consumed annually in these products amounts to 25 million pounds, of which approximately 10 to 12 million pounds are used, when blended with linseed, perilla, or tung oils, in the production of exterior paints. These blended paint oils generally contain 20 to 45 percent of soybean oil, but small quantities of 100-percent soybean oil paint are currently marketed. For use in paints soybean oil should be alkali- or mechanically-refined, and it may also be blown or oxidized to improve the drying and gloss of the paint film. When mixed with linseed oil in amounts up to 30 percent, refined soybean oil increases the elasticity of the paint film without materially affecting the drying time. Such films flow more freely and work better under the brush than do similar films prepared with pure linseed oil. Lead-manganese and cobalt driers, preferably in the form of resinates and linoleates, or lead-manganese eleostearates, when used with these mixtures, produce films which dry fairly hard within 24 hours.

Pigments grind readily in soybean oil, and it is especially suitable for the production of soft pastes which hold their tints remarkably well and do not harden on long standing. Because of the latter characteristic soybean oil is especially suited for the preparation of caulking compounds and plastic ship bottom paints. Crude, semirefined, and varnish grade soybean oils, either alone or when mixed with linseed oil, have been used as core oils; and cores made with soybean oil or soybean-linseed oil mixtures have been found to have suitable tensile strengths for most foundry operations.

Crude expeller and similarly pressed oils, when kettle-bodied, generally tend to darken and even to break with the separation of highly colored gummy materials and the production of an orange-colored oil. Consequently, crude oils of this type are not suitable for the production of varnishes. However, after alkali- or mechanical-refining, these oils show no break when heated to 288° C. and above, and tend to bleach at elevated temperatures. Furthermore, refined soybean oil is remarkably free from yellowing and discoloration when used in white or light tinted products applied to interior walls or objects exposed only to artificial or diffused light. This superior color retention, as well as its freedom from wrinkling, makes it highly suitable for use in heat-reactive resin formulations such as baking alkyd resins. As a consequence of these properties, soybean oil has found a very definite place in the production of modified synthetic resins for use in baking alkyds and in similar air-drying enamels. These products are prepared in a variety of ways, either directly from soybean oil or from its derived fatty acids.

More recent practice involves heating soybean oil with an excess of glycerol to convert it to the monoglyceride and adding, toward the end of the reaction, minor amounts of tung or other oils to improve the ultimate water resistance of the finished product, which in turn is followed by the addition of phthalic or other acid anhydride, and completion of the reaction by further heating. The final reaction products, or alkyd resins as they are called, find extensive use in finishing motor cars, refrigerators, and similar metal products.

Edible Products

In recent years the principal outlet for soybean oil has been in the edible field and, as mentioned above, it is essential that the oil be refined, bleached, winterized, and deodorized to remove part or all of the color and odorous constituents. These operations are highly technical and are carried out on a large scale. The completely refined oil can be used as a salad oil and in the preparation of mayonnaise and salad dressings, in packing fish, and in deep-fat frying of such food products as potato chips, nuts, and doughnuts. For these purposes it is usually blended with cottonseed, corn, or similar oils. Because of the tendency of highly refined soybean oil to undergo flavor reversion, care must be exercised in its use in edible products. Because of the high tinctorial properties of soybean oil it can be used to produce a bright-colored mayonnaise and for coloring oleomargarine.

In the production of shortening and oleomargarine, soybean oil is hydrogenated after it is refined, and then bleached and deodorized. For use in the manufacture of oleomargarine it is usually blended with some other oil, especially cottonseed or coconut oils, although considerable quantities of oleomargarine made wholly from milk and soybean oil are currently produced. In this case the oil is usually hydrogenated to an iodine number of about 75. Whole milk is inoculated with a mixed culture and incubated or ripened to produce the necessary amount of lactic acid and flavoring constituents required to impart the essential butter flavor to the finished product. After introduction of the salt and other minor ingredients, the milk and hydrogenated oil are properly proportioned and fed to the emulsifying churns or high-speed homogenizers, where they are emulsified to form a creamy liquid which on crystallization forms the finished product known as oleomargarine.

By far the largest single outlet for soybean oil is in the production of vegetable shortenings and lard compounds. For these uses the oil is hydrogenated to a degree of hardness which depends on the experience of the manufacturer and the type of product desired. The hydrogenated oil is blended with other fats and oils, especially hydrogenated cottonseed oil. In some cases the soybean oil is hardened to a rather high titer and blended with less highly-hydrogenated cottonseed or other oil in order to improve the flavor stability and retain the requisite plasticity in the finished product.

Phosphatides

Soybean oil contains a variable mixture of glycerophosphoric acid esters which are collectively designated as phosphatides. The apparent phosphatide content of the oil varies with the method by which it is removed from the seed, but generally ranges from 1.5 to 3.0 percent. The mixed phosphatides comprise both lecithins and cephalins, the former being present to the extent of about 30 to 35 percent of the total. Lecithins are distinguishable from the cephalins by their ready solubility in alcohol and ether in contrast to the lesser solubility or complete lack of solubility of the latter in alcohol.

The commercial soybean lecithins consist of a group of closely related compounds whose properties vary somewhat with the source and method of manufacture. So-called soya lecithin is usually produced from solvent-extracted oil by hydration and subsequent separation of oil and phosphatides in high speed centrifugals. About 30 percent of oil remains in some loose combination with the phosphatides and serves as a carrier and inhibitor of oxidation to which the phosphatides are especially susceptible. After drying in vacuo to remove the water used in hydrating the phosphatides, the product may be bleached to reduce the color. Commercial soya lecithin is available in a number of grades and in carriers other than soybean oil. The product is used in small quantities as an emulsifying, wetting, or stabilizing agent in a large variety of products including confections, pharmaceuticals, shortening, and textile and leather finishes.

Sterols

The unsaponifiable fraction, amounting to 0.5 to 2 percent of the original crude soybean oil, is of little commercial value at the present time. Somewhat less than half of the total unsaponifiable matter of the crude oil consists of a mixture of sterols, principally sitosterols, dihydrositosterol, and stigmasterol. During the process of alkali refining, a portion of the unsaponifiable matter is separated from the oil along with the soap stock. After acidulation and distillation of the soap stock, the unsaponifiable matter accumulates in the pitch, or still residue, from which the crude mixed sterols can be separated by solvent extraction. The same mixed sterols may also be obtained by saponifying crude phosphatide residues and working up the unsaponifiable fraction.

Because of the interest in stigmasterol as a source material for the preparation of certain sex hormones, the recovery of this substance from the crude mixed sterols has attracted considerable attention. The stigmasterol content of crude oil is probably not over 0.1 percent and its recovery entails many operations of a highly technical character.

Vitamins

The vitamins present in soybean oil have not been completely characterized, and the effect of various processing treatments on these substances is for the most part unknown. Such information as is available indicates that crude soybean oil is moderately rich in growth-promoting vitamin A, but relatively poor or completely lacking in the antirachitic vitamin D. The antisterility vitamin E content of crude soybean oil appears to be quite low. The presence of the antihemorrhagic vitamin K has been reported although in relatively low concentration. The literature contains a number of reports with reference to nutritional factors which cannot be related to any presently known vitamin. The crude oil appears, for example, to contain a preventive against nutritional encephalomalacia in chicks and nutritional muscular dystrophy in rabbits.

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